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7/25/68

PHOTOCHEMICAL BEHAVIOR OF 6,7a-DIMETHYL-5(7aH)-INDANONE IN ACIDIC MEDIA

A THESIS

Presented to

The Faculty of the Graduate Division

by

John Thomas Gupton III

In Partial Fulfillment

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Master of Science in Chemistry

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PHOTOCHEMICAL BEHAVIOR OF 6,7a-DIMETHYL-5(7aH)-INDANONE IN ACIDIC MEDIA

Approved:

Chairman

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GLOSSARY OF ABBREVIATIONS

vpc	vapor phase chromatography
SE-30	silicone gum rubber (methyl)
DDQ	2,3-dicyano-5,6-dichlorobenzoquinone
TMS	tetramethylsilane, nmr standard

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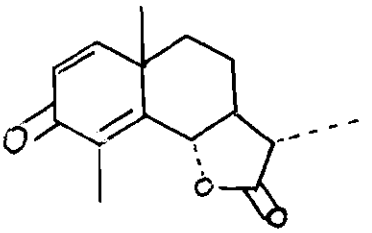
SUMMARY

It was the purpose of this research to investigate the photochemical behavior of 6,7a-dimethyl-5(7aH)-indanone in acidic media. This was accomplished by irradiating the indanone in methanolic acetic acid and aqueous acetic acid, after it had been synthesized through a sequence of known reactions. The structures of the photoproducts were established by their chemical and spectral properties after their isolation by well established chromatographic techniques. It had been previously found that irradiation of the analogous 6/6-fused cross conjugated cyclohexadienone in acidic media yielded a spirocyclic compound as the major product. Upon irradiation of 6,7a-dimethyl-5(7aH)-indanone in acidic media it was found that 5/6-fused ring systems and tricyclic compounds were obtained. This behavior is therefore in extreme contrast to the 6/6-system and could be attributed to the photochemical reactivity of the expected spiro compound or the nature of the ring strain in the mesoionic intermediate.

CHAPTER I

INTRODUCTION

In the past several years there has been a great deal of interest in photochemical reactions as a result of the stereospecifity of such reactions and the utility of such reactions in natural product synthesis. Of particular interest to natural product chemists has been the study of the photochemical rearrangements of cross conjugated cyclohexadienones. The initiation of such work was done by Jeger (1) and Barton (2) in connection with the sesquiterpene α-santonin(I). When irradiation of such compounds was carried out in an inert solvent,



I

such as dioxane, tricyclic compounds were obtained. When the irradiation was carried out in a protic solvent, such as aqueous acetic acid, the products were 5/7-fused ring systems, spiro (4.5) systems, and phenols.

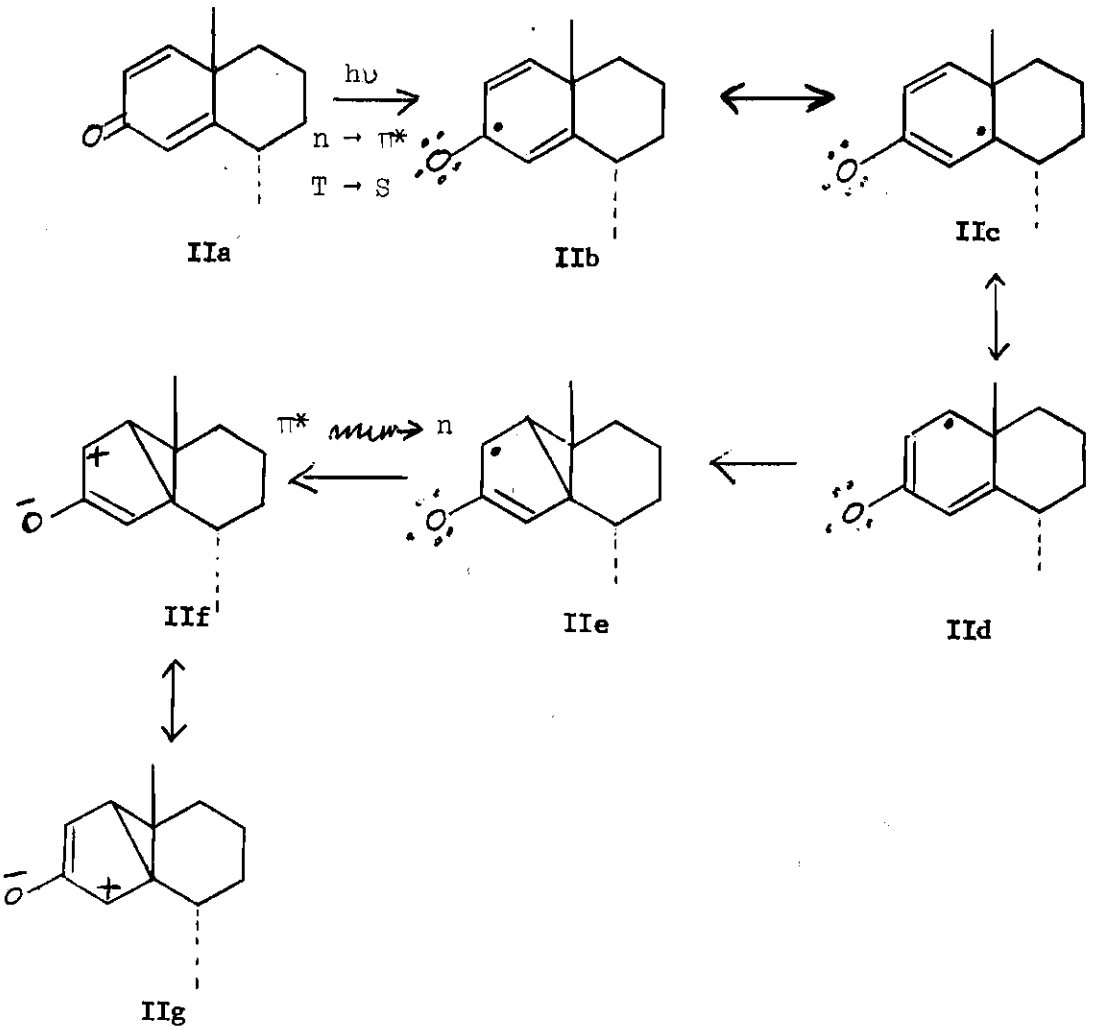
The exact mechanisms for these reactions have not been established but many well accepted details concerning the nature of such reactions have been reported.

The excited state intermediate is thought to be a triplet on the basis that the triplet excitation can be transferred from photosensitizers, such as benzophenone(3) to α-santonin, and that triplet quenchers such as piperylene have been found to completely quench the rearrangement reactions (3,4). The transition which is thought to be involved is an $n \rightarrow \pi^*$ state on the basis of phosphorescence studies (3).

The intervention of a zwitterionic intermediate in such reactions is widely accepted. The notation for the proposed mechanism has been set forth by Zimmerman and Schuster (5) and Taylor (6). Zimmerman, however, has criticized the Taylor notation on the basis that it fails to show the state of the excited electrons. Compound IIa, studied by Kropp and Erman (7), has been used to illustrate these notations.

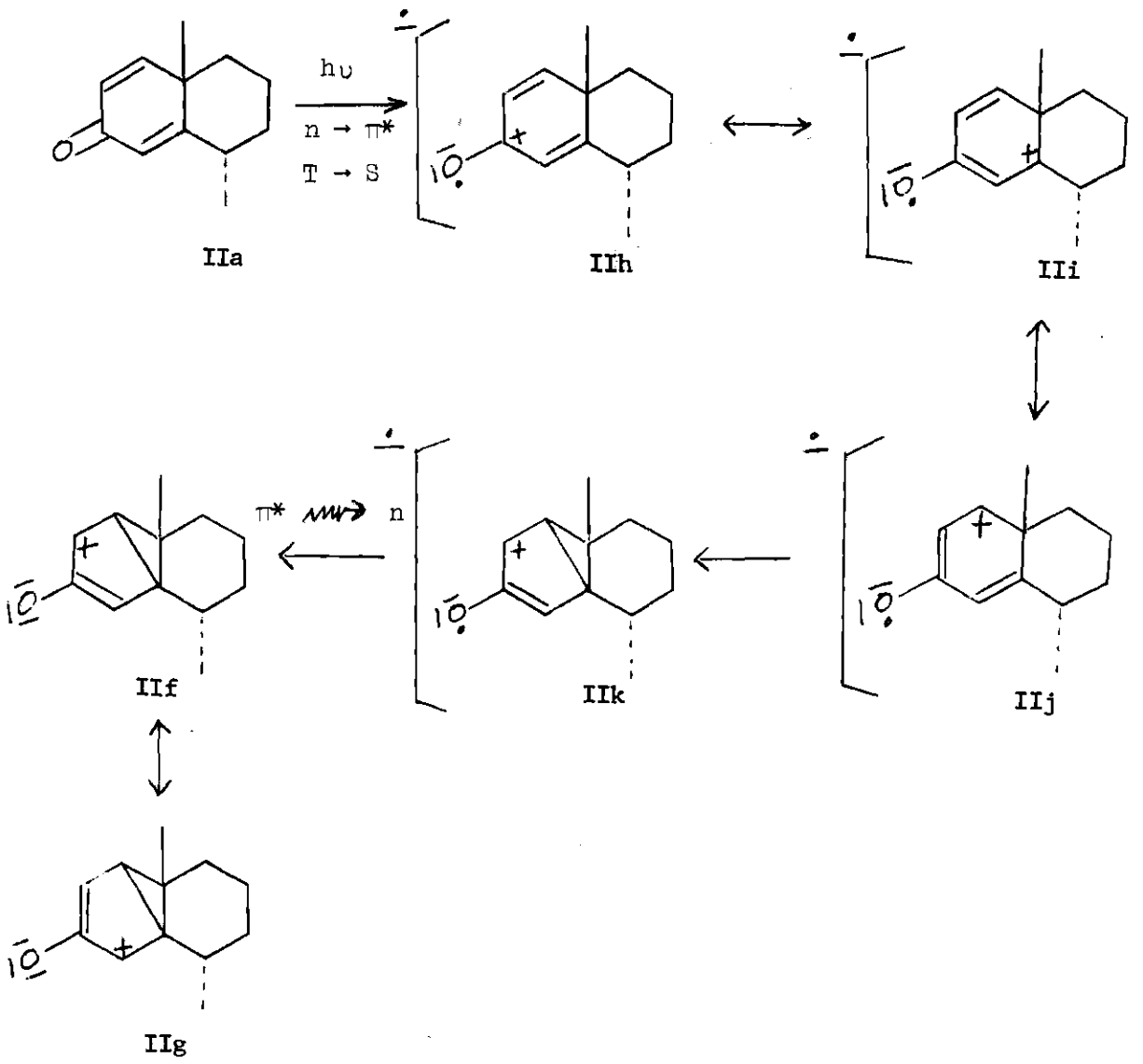
Zimmerman Notation

Equation 1

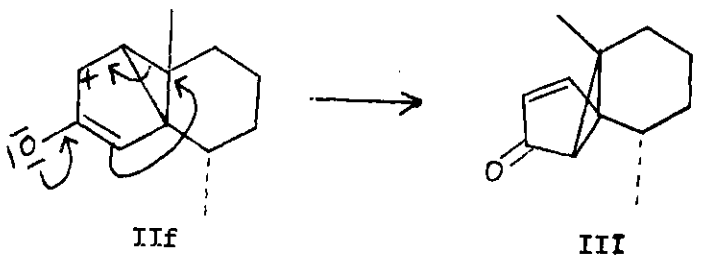


Taylor Notation

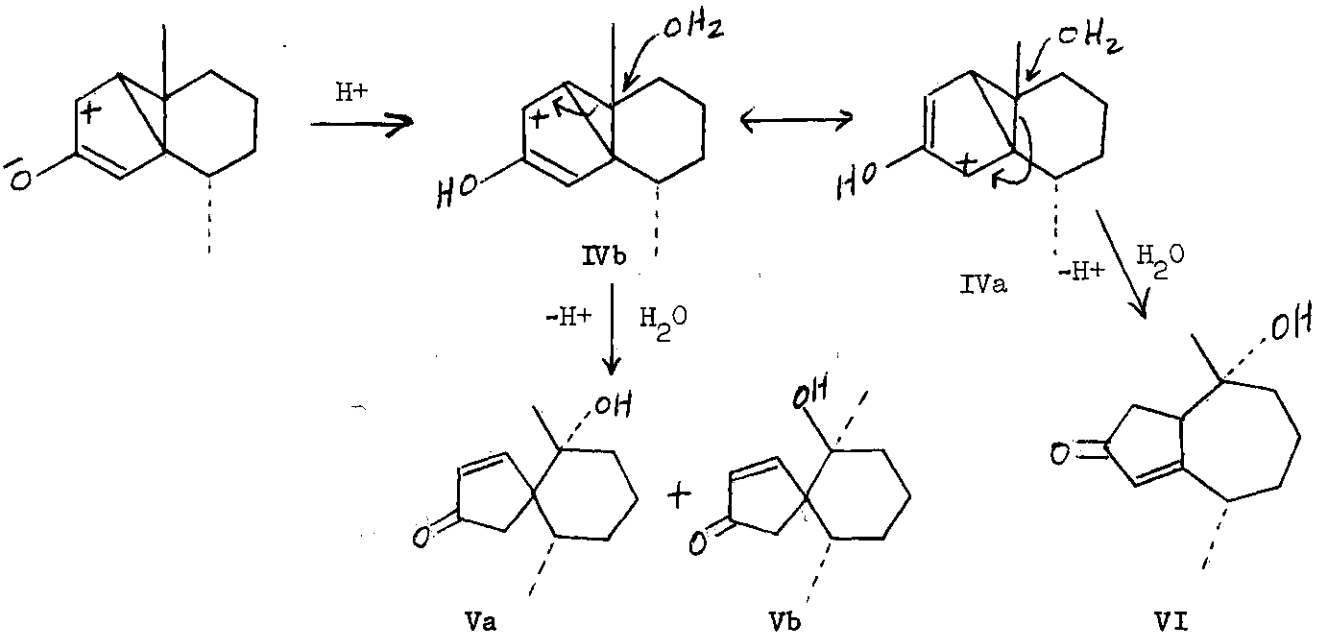
Equation 2



Equation 3

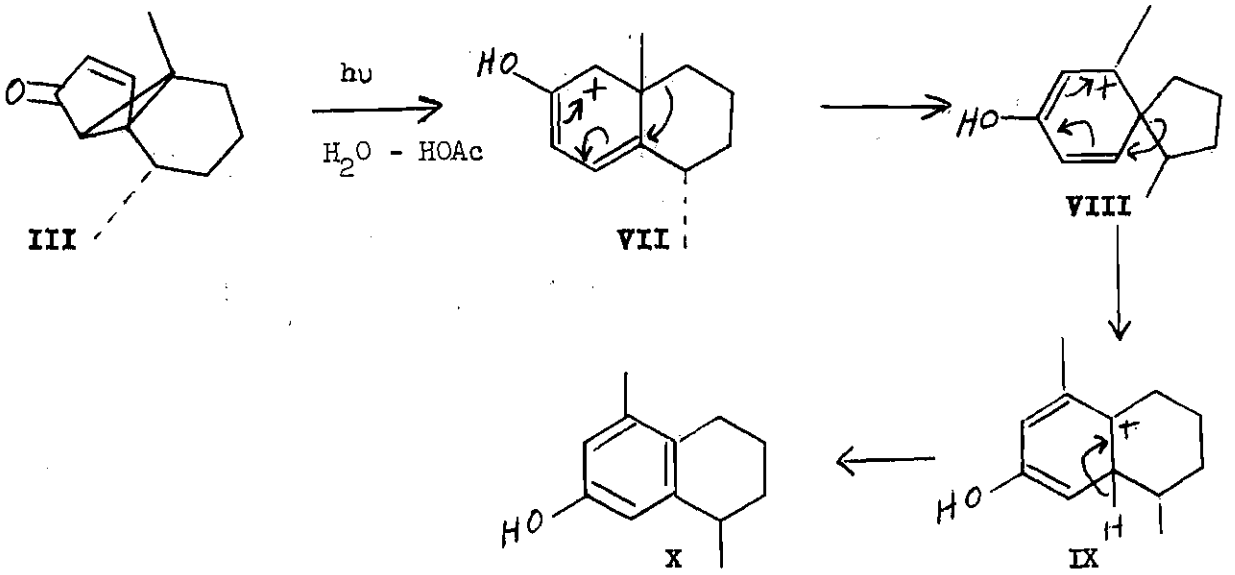


Equation 4



In the case of irradiation in a protic media, as in equation four, once the mesoionic intermediate (IVa, IVb) is formed it is collapsed by solvent attack at C_9 to give either spiro compounds (Va, Vb) or fused systems (VI) by breaking the C_1-C_9 bond or C_9-C_{10} bond respectively.

Equation 5



The formation of phenolic compounds in the case of irradiation of cross conjugated systems in protic solvents is illustrated by equation five. Once the lumiproduct (compound III) has formed it can rearrange photochemically to a phenol.

Since irradiations in both protic and inert solvents involve cationic and zwitterionic intermediates respectively, one would suspect that the character of the groups at positions two and four would have a marked effect on what type of products are formed. Extensive studies have been done in this area and the following information has been obtained in relation to 6/6-fused cross conjugated cyclohexadienones.

(1) Compounds without a methyl substituent at C_2 or C_4 in the A ring give lumiproducts in inert solvents and mixtures of spiro hydroxyketones, 5/7-fused hydroxyketones and phenols in aqueous acetic acid.

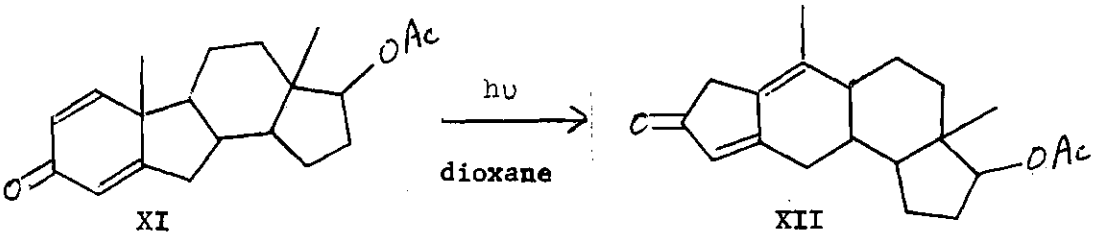
(2) Compounds with a methyl group at the two position give

predominantly lumiproducts in inert solvents and spiro hydroxyketones in aqueous acetic acid.

(3) Compounds with a methyl group at the four position give chiefly lumiproducts in inert solvents and fused 5/7-hydroxyketones in aqueous acetic acid.

Very little work has been reported in the literature on photochemical rearrangements of 6/5-cross conjugated systems. Jeger and coworkers (8) have reported that irradiation of the B-nor-steriodal dienone (XI) in anhydrous dioxane at 2537 Å gave the linear conjugated dienone (XII) in 68 per cent yield.

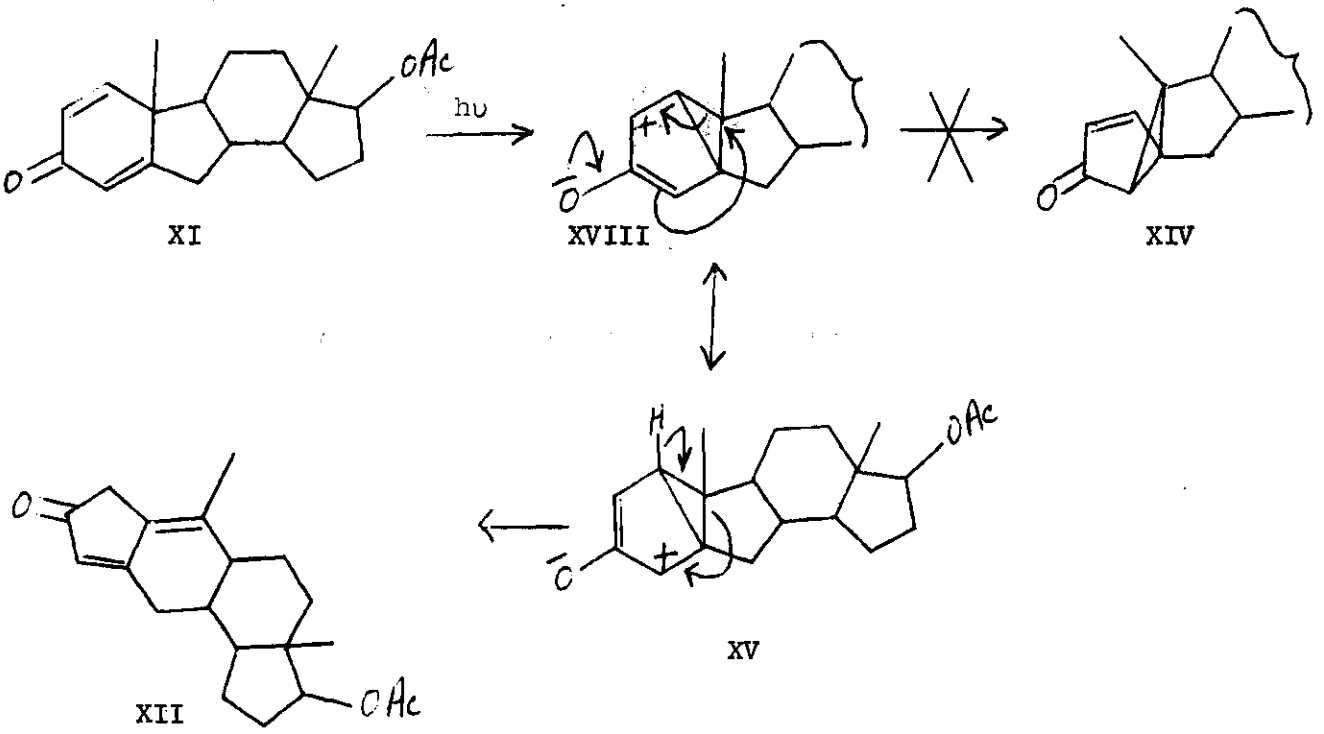
Equation 6



XI XII

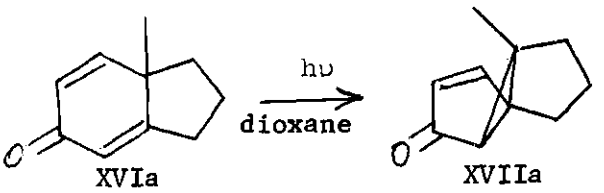
The expected lumiproduct is thought not to form because of the ring strain involved in [5.3.5]-tricyclic systems.

Equation 7

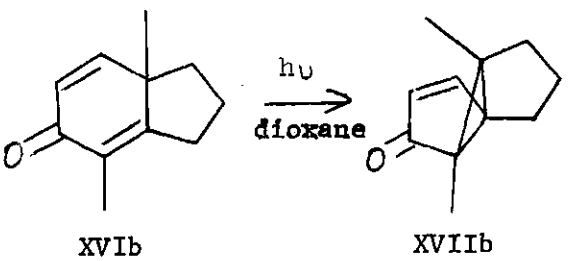


Caine and coworkers (9, 10) have found that irradiation of compounds XVIa, XVIb and XVIc yield lumiproducts in dioxane.

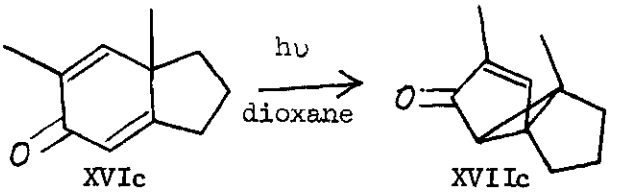
Equation 8



Equation 9

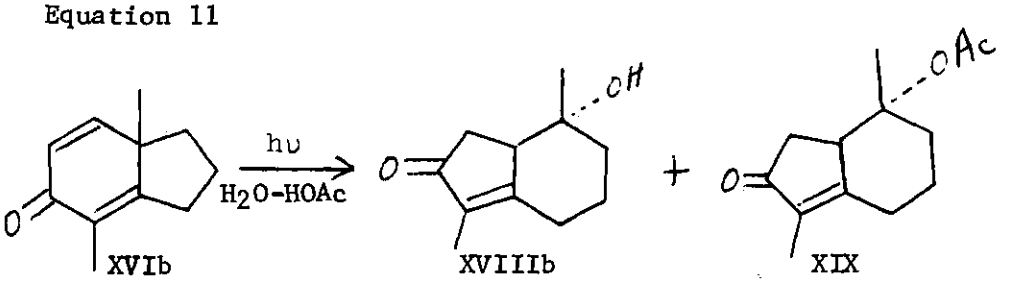


Equation 10

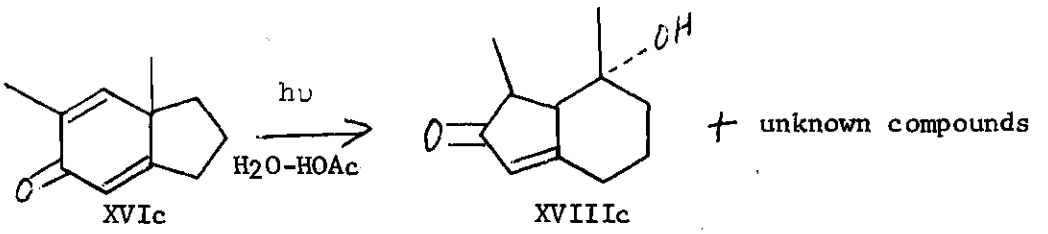


Powers (9) has also found that irradiation of compound XVIb in aqueous acetic acid yielded a 5/6-fused hydroxyketone (XVIIIb) as the major product. Upon irradiation of compound XVIc in aqueous acetic acid the unexpected 5/6-fused hydroxyketone (XVIIIc) was obtained in ca. 30 per cent yield along with several unidentified compounds.

Equation 11



Equation 12



It was the purpose of this research to establish the structures of the unidentified compounds produced in the irradiation of compound XVIc in

acidic media and in so doing extend the knowledge of photochemical reactions of 5/6-fused cross conjugated systems.

CHAPTER II

INSTRUMENTATION AND EQUIPMENT

Ultraviolet spectra were recorded on a Cary Model 14 recording spectrophotometer using one centimeter cells and 95 per cent ethanol as the solvent. Near infrared spectra were also recorded on the Cary Model 14 using one centimeter quartz cells and carbon tetrachloride as the solvent. Infrared spectra were obtained on a Perkin Elmer 457 spectrophotometer. Proton magnetic resonance spectra were recorded on a Varian A-60D or a Japan Electronics Optics Lab JNM 4H-100 spectrometer using carbon tetrachloride as the solvent. Positions of nmr absorptions are reported in ppm downfield from tetramethysilane (TMS). The abbreviations s, d, t, q, and m refer respectively to singlet, doublet, triplet, quartet, and multiplet. Mass spectra were recorded on a Varian M-66 mass spectrometer. Solvents were removed with a commercial rotating evaporator unless otherwise stated. All inorganic chemicals used were reagent grade. Technical grade hydrocarbon solvents were used and were distilled prior to use. A Hanovia 450 watt high pressure arc source, used in an all pyrex apparatus similar to that described by Kropp and Erman (7), was employed in all irradiation experiments. Solutions were deoxygenated prior to irradiation and agitated during irradiation with a stream of nitrogen. Vapor phase chromatographic studies were conducted on a Perkin Elmer 881 gas chromatograph equipped with 10 foot columns of SE-30 on chromosorb W.

CHAPTER III

EXPERIMENTAL

Methyl Isopropenyl Ketone (XXXII)

This compound was prepared by the method of Morgan, Megson, and Pepper (11). Two hundred ml of 2-butanone and 150 ml of 45 per cent aqueous formaldehyde were placed in a one liter three necked round bottomed flask equipped with a mechanical stirrer and reflux condenser. The flask was placed under positive nitrogen flow and two ml of 2N sodium hydroxide were added. The mixture was then heated on a steam bath until an exothermic reaction had begun. The external heating was discontinued and the mixture was allowed to reflux for two hr. and then allowed to stir for 14 hr. During the two hr. of reflux it was necessary to add one ml aliquots of 2N sodium hydroxide in order to keep the reaction mixture basic. The reaction mixture was worked up by neutralization with glacial acetic acid and distilling it under reduced pressure. Eighty four and three tenths grams of the desired 3-hydroxymethyl-2-butanone were collected at 88-110° under a pressure of 15 mm. The crude 3-hydroxymethyl-2-butanone was then placed in a 100 ml round bottomed flask along with 0.937 g of oxalic acid and distilled through a four inch vigreaux column. Seventy two and two tenths grams of the water azeotrope of methyl isopropenyl ketone were collected and dried with anhydrous magnesium sulfate. The dried ketone was then distilled at atmospheric pressure using a four inch vigreaux column. This yielded 31.6 g of the isopropenyl ketone.

6,7a-Dimethyl-7,7a-dihydro-5(6H)-indanone (XXX)

Six grams (0.107 moles) of potassium hydroxide were dissolved in ca. 50 ml of absolute ethanol by heating the mixture on a steam bath overnight. Forty eight and three tenths grams (0.498 moles) of 2-methylcyclopentanone were placed in a dried 500 ml three necked round bottomed flask, which had been fitted with a magnetic stirrer and a dropping funnel. To this flask was added the alcoholic potassium hydroxide solution along with 200 ml of anhydrous ether. The reaction mixture was then cooled to -5° in a nitrogen atmosphere and 32.8 g (0.390 moles) of methyl isopropenyl ketone dissolved in ca. 50 ml of ether was added dropwise such that the temperature of the reaction mixture remained at -5°. After the addition was complete, the ice bath was removed and the mixture was stirred for one hr. The mixture was then poured into 400 ml of 10 per cent hydrochloric acid. The layers were separated and the aqueous layer was extracted with several 50 ml portions of ether. The combined organic layers were dried with anhydrous magnesium sulfate and the solvents were removed in vacuo. Short path distillation at reduced pressure gave nine grams of 2-methylcyclopentanone (b.p. 41-45°/18 mm). Further distillation gave 40.0 g of tractable materials (b.p. 50-125°/1.5 mm). The tractable materials were dissolved in 200 ml of 10 per cent ethanolic potassium hydroxide and refluxed with stirring for 75 min. The mixture was cooled, neutralized with glacial acetic acid, and the solvents were removed in vacuo. Water was added to dissolve the potassium acetate formed and the layers were separated. The water layer was extracted with two 50 ml portions of ether and the combined organic layers were dried over anhydrous magnesium sulfate. The

solvents were removed in vacuo leaving a yellow oil which was distilled through a short path distilling head under reduced pressure. The two fractions which were collected boiled at 41-65°/.75 mm. and 106-135°/.75 mm. Vapor phase chromatographic analysis showed that the lower boiling fraction contained a mixture of the desired indenone and acetic acid and the higher boiling fraction contained exclusively the desired indenone (compound XXX). A total of 37.5 g (70 per cent) of the indenone was obtained.

Compound XXX exhibited the following properties: uv max (95 per cent ethanol) 238 mu (ϵ = 10,700); ir(CCl_4) 3.37, 3.41, 3.48, 5.97 (C=O) and 6.85 μ (C=C); nmr δ 5.65 (m, 1H), 1.25-1.87 (broad absorption, 9H), 1.19 (s, 3H), 1.07 (d, 3H, J = 7.0 Hz); mass spectrum (70 eV) m/e 164 (M^+).

Anal. $C_{11}H_{16}O$ Calcd: C, 80.41 H, 9.86
Found: C, 80.20 H, 9.84

6,7aDimethyl-5(7aH)-indanone (XVIc)

This compound was prepared by a modification of the method of Bloom (12). Into a dried one liter three necked round bottomed flask equipped with magnetic stirrer, reflux condenser, and dropping funnel was placed ca. 750 ml of freshly distilled t-butyl alcohol along with 25.4 g (0.229 moles) of selenium dioxide, which had been freshly sublimed, and 21 ml of glacial acetic acid. After the selenium dioxide had dissolved, 37.5 g (0.229 moles) of compound XXX, dissolved in 75 ml of anhydrous ether, were added dropwise and the resulting mixture was refluxed for 46 hr. under a nitrogen atmosphere. After this period

of time, the reaction mixture was cooled to room temperature and the selenium metal formed was removed by suction filtration leaving a dark filtrate. The solvents were removed from the filtrate *in vacuo* leaving a black viscous mass. This residue was distilled at reduced pressure yielding tractable materials boiling between 95 and 135° at 0.5 mm. Six and five tenths grams of the distillate were placed on a column of 142.5 g of silica gel and eluted with hexane-ether mixtures. Compound XXX was eluted from the column with five per cent ether-hexane. Compound XVIc was eluted from the column with 20 per cent ether-hexane. Compound XXI was eluted from the column with 50 per cent ether-hexane.

Compound XVIc exhibited the following properties: uv max (95 per cent ethanol) 244 mu (ϵ = 12,900); ir(CCl_4) 3.36, 3.41, 3.45, 5.97 (C=O) and 6.14 μ (C=C); nmr δ6.72 (q, 1H, J = 1.57 Hz), 5.88 (t, 1H, J = 1.8 Hz), 1.41-2.92 (broad absorption, 6H), 1.79 (d, 3H, J = 1.5 Hz), 1.18 (s, 3H); mass spectrum (70 eV) m/e 162 (M^+).

Anal. $C_{11}H_{14}O$ Calcd: C, 81.44 H, 8.70

Found: C, 81.57 H, 8.91

Compound XXI exhibited the following properties: nmr δ 6.12 (s, 1H), 1.72-2.69 (broad absorption, 7H), 1.36 (s, 3H), 1.14 (d, 3H, J = 7 Hz); mass spectrum (70 eV) m/e 178 (M^+); ir (CCl_4) 3.38, 3.42, 3.48, 5.78 (C=O), 5.95 (C=O) and 6.11 μ (C=C). uv max (95 per cent ethanol) 252 mu (ϵ = 10,200).

Inadiation of 6,7a-Dimethyl-5(7aH)-indanone in 45 per cent Aqueous Acetic Acid

Compound XVIc, 2.240 g (0.38 moles), was dissolved in *ca*. 300 ml of 45 per cent aqueous acetic acid and irradiated with a 450 watt

Hanovia high pressure arc source for 105 min. The solvents were removed in vacuo by azeotropic evaporation with toluene, and the oil obtained was placed on a column of 61.0 g of silica gel and eluted with hexane-ether mixtures. Elution with 10 per cent ether-hexane gave 1.03 g (46 per cent) of compound XVIc. Elution with 60 per cent ether-hexane gave 0.470 g (19 per cent) of compound XXII. Elution with 75 per cent ether-hexane gave 0.423 g (17 per cent) of compound XVIIIc. Elution with 100 per cent ether gave 0.457 g (18 per cent) of compound XVIIIb.

Compound XXII exhibited the following properties: ir (CCl_4) 1.659, 2.77, 2.92, 3.46, 3.49 and 5.79 μ (C=O); nmr δ 4.06 (s, 1H), 1.42-2.96 (broad absorption, 7H), 2.49 (d, 1H, J_{AB} = 18 Hz), 2.21 (d, 1H, J_{AB} = 18 Hz), 1.20 (s, 3H); uv max (95 per cent ethanol) 219 mu (ε = 3,200); exact mass 180.155 (calculated 180.155).

Compound XVIIIc exhibited the following properties: m.p. 70.5-71.0°; uv max (95 per cent ethanol) 234 mu (ε = 16,500); ir (CCl_4) 2.77, 2.92, 5.84 (C=O), and 6.13 μ (C=C); nmr δ 5.81 (m, 1H), 1.50-3.39 (broad absorption 9H), 1.30 (d, 3H, J = 7.5 Hz), 0.92 (s, 3H); mass spectrum (70 eV) 180 (M^+).

Anal. $C_{11}H_{16}O_2$ Calcd: C, 73.30 H, 8.95
Found: C, 73.10 H, 8.96

Compound XVIIIb exhibited the following properties: nmr - δ 4.15 (s, 1H), 1.20-3.00 (broad absorption, 9H), 1.62 (d, 3H, J_{AB} = 1 Hz), 0.88 (s, 3H); ir (CCl_4) 2.78, 2.93, 3.40, 3.48, 5.87 (C=O) and 6.05 μ (C=C); uv max (95 per cent ethanol) 237 mu (ε = 17,400); exact mass 180.119 (calculated 180.113).

Irradiation of 6,7a-Dimethyl-5(7aH)-indanone in 45 per cent Methanolic acetic acid

Compound XVIc, 1.30 g (0.00802 moles), was dissolved in ca. 300 ml of 45 per cent acetic acid in methanol solution and was irradiated with a 450 watt Hanovia high pressure arc source for 90 min. Solvents were then removed in vacuo leaving a brown oil. Vapor phase chromatographic analysis of the oil on a 10 foot column of SE-30 showed 3 major peaks in addition to starting material. The reaction mixture was then placed on a column of silica gel and eluted with hexane-ether mixtures. Compound XVIc was eluted from the column with 10 per cent ether-hexane. Elution with 25 per cent ether-hexane yielded 0.326 g (21 per cent) of compound XXIII. Elution with 50 per cent ether-hexane gave 0.470 g (31 per cent) of compound XXIV. Elution with 75 per cent ether-hexane gave 0.280 g (18 per cent) of compound XXV.

Compound XXIII exhibited the following properties: ir (CCl_4) 1.652, 3.41, 3.50, 3.58, and 5.80 μ (C=O); uv max (95 per cent ethanol) 223 mu (ϵ = 2,900), 297 mu (ϵ = 1,500); nmr 3.24 (s, 3H), 2.55 (d, 1H, J = 18 Hz), 2.22 (d, 1H, J = 18 Hz) 1.50-1.94 (broad absorption, 7H), 1.22 (s, 3H), 1.18 (s, 3H); exact mass 194.130 (calculated 194.131).

Anal. $C_{11}H_{18}O_2$ Found: C, 74.18 H, 9.38

Calcd: C, 74.13 H, 9.27

Compound XXIV exhibited the following properties: ir (CCl_4) 3.39, 3.48, 3.53, 5.87 (C=O) and 6.16 μ (C=C); uv max (95 per cent ethanol) 233 mu (ϵ = 14,500); nmr δ 5.72 (m, 1H), 3.22 (s, 3H), 1.24-3.12 (broad absorption, 8H), 1.11 (d, 3H, J_{AB} = 7 Hz), 0.98 (s, 3H); exact mass 194.131 (calculated 194.141).

Compound XXV exhibited the following properties: ir (CCl_4) 3.40, 3.48, 3.52, 5.87 (C=O) and 6.02 μ (C=C); nmr δ 3.18 (s, 3H), 1.01-2.93 (broad absorption, 9H), 1.61 (d, 3H, J = 1 Hz), 0.88 (s, 3H); exact mass 194.131 (calculated 194.131).

Treatment of 2,9-Dimethyl-5-methoxytricyclo-[4.3.0^{2,9}]-3-nonanone (XXIII) with Lithium in Ammonia

Compound XXIII, 0.120 g (0.000618 moles), was dissolved in 50 ml of anhydrous ether and added dropwise to ca. 250 ml of dry ammonia, which contained 0.030 g of lithium metal, in a 500 ml three necked round bottomed flask equipped with mechanical stirrer, acetone-dry ice condenser and dropping funnel. The mixture was stirred for one hr. after which excess ammonium chloride was added and the resulting reaction mixture was stirred for 30 min. The ammonia was then evaporated from the reaction mixture by allowing it to stand at room temperature overnight. To the ethereal solution remaining was added ca. 40 ml of water and the layers were separated. The water layer was extracted several times with ether and the combined organic layers were dried over sodium sulfate. The solvents were removed in vacuo leaving a brown oil. Infrared and nmr data showed the oil to consist of primarily compound XXVI along with a small amount of compound XXIII. Vapor phase chromatographic analysis on a 10 foot column of SE-30, however, showed the presence of three compounds. One of the components was found to have the same retention time as compound XXIII. Preparative vapor phase chromatographic analysis of the reaction mixture on a 10 foot column of SE-30 showed the component which did not appear in the nmr and ir data prior to vpc studies to be compound XXVII by its ir

absorptions at 5.88 (C=O) and 6.18 μ (C=C). The reaction mixture was then distilled at reduced pressure yielding a colorless oil (compound XXVI) which exhibited the following properties: ir (CCl_4) 3.41, 3.48, 3.53 and 5.72 μ (C=O); exact mass 196.149 (calculated 196.149); nmr δ 3.12 (s), 3.18 (d, J_{AB} = 14 Hz), 2.21 (d, J_{AB} = 14 Hz), 2.20 (s), 1.30-2.12 (broad absorption), 1.12 (d, J = 6.5 Hz), 0.97 (d, J = 7 Hz); uv max (95 per cent ethanol) no uv absorption above 200 mu.

Treatment of 1,7-Dimethyl-4a-methoxy-2-indanone (XXVI) with Sodium Hydride

Compound XXVI, 0.1534 g (.000785 moles), was added to 0.0465 g of sodium hydride in 25 ml of dimethoxyethane in a three necked round bottomed flask equipped with magnetic stirrer and condenser. The resulting reaction mixture was placed under nitrogen flow and stirred for two hours after which time 30 ml of water and 50 ml of ether were added. The layers were separated and the water layer was extracted several times with ether, The combined organic layers were dried over sodium sulfate. The solvents were removed *in vacuo* leaving 0.102 g of a yellow oil. Vapor phase chromatography showed the reaction mixture to consist of *ca*. 92 per cent compound XVII and *ca*. eight per cent compound XXVI. The yellow oil was distilled at reduced pressure yielding a colorless oil which exhibited the following properties: uv max (95 per cent ethanol) 233 mu (ε = 11,300); ir (CCl_4) 3.38, 3.41, 3.48, 5.88 (C=O) and 6.18 μ (C=C); nmr 5.82 (m, 1H), 1.70-313 (broad absorption, 9H), 1.19 (d, 3H, J = 8 Hz), 0.92 (d, 3H, J = 7 Hz); exact mass 164.116 (calculated 164.120).

Treatment of 2,9-Dimethyl-5-methoxytricyclo-[4.3.0^{2,9}]-3-nonanone (XXIII) with Sodium Hydride

Compound XXIII, 0.0838 g (0.000432 moles), was added to 0.0107 g of sodium hydride in 25 ml of 1,2-dimethoxyethane in a three necked 50 ml round bottomed flask equipped with magnetic stirring and condenser. The resulting reaction mixture was placed under nitrogen flow and stirred for two hours after which time 30 ml of water and 50 ml of ether were added. The layers were separated and the water layer was extracted several times with ether. The combined organic layers were dried over sodium sulfate and the solvents were removed *in vacuo* leaving a yellow oil. Infrared and vpc analysis of the oil showed it to be entirely compound XXIII.

Treatment of 2,9-Dimethyl-5-hydroxytricyclo-[4.3.0^{2,9}]-3-nonanone (XXII) with Thionyl Chloride in Pyridine

Compound XXII, 0.100 g (0.000555 moles), was placed in an nmr tube along with a small amount of pyridine and the resulting solution was cooled to zero degrees at which time a few drops of thionyl chloride were added. The reaction was monitored by nmr but took place in such a manner that nothing could be discerned from the nmr data obtained. The reaction was quenched after *ca.* 15 min. by pouring the reaction mixture into 25 ml of ice water. Twenty-five ml of ether were added and the layers were separated. The water layer was extracted several times withether and the combined organic layers were dried over sodium sulfate. The solvents were removed *in vacuo* leaving a yellow oil which in the case of vpc analysis showed the presence of three new compounds. No compounds could be isolated from the reaction mixture however. Infrared analysis of the crude reaction mixture showed absorptions at

2.78, 3.41, 3.48, 5.77 (C=O) and 6.17 μ (C=C).

Treatment of 2,9-Dimethyl-5-hydroxytricyclo-[4.3.0^{2,9}]--3-nonanone (XXII) with Periodic Acid

Compound XXII, 0.0664 g (0.000369 moles), was dissolved in 50 ml of a 50 per cent water-dioxane mixture along with 0.8633 g of periodic acid in a 125 ml erlenmyer flask equipped with a magnetic stirrer. The mixture was stirred for 25 hr. Fifty ml of ether and 24 ml of water were added and the layers were separated. The water layer was extracted several times with ether and the combined organic layers were dried over sodium sulfate. The solvents were removed *in vacuo* leaving a black viscous oil. Infrared and nmr analysis of the oil indicated a reaction had taken place but no products could be isolated.

Attempted Hydrogenation of 2,9-Dimethyl-5-methoxy-tricyclo-[4.3.0^{2,9}]-3-nonanone (XXIII)

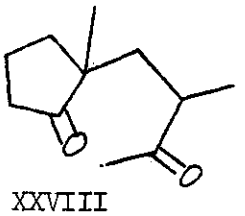
Compound XXIII, 0.0727 g (0.000371 moles), was dissolved in *ca.* 25 ml of absolute ethanol along with 0.0483 g of palladium on charcoal and hydrogenated for 7 d. Infrared analysis of the reaction mixture indicated that no reaction had taken place.

CHAPTER IV

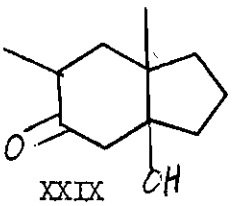
DISCUSSION OF RESULTS

Although the objective of this research was to study the photochemical behavior of 6,7a-dimethyl-5(7aH)-indanone (XVIc) in acidic media, it will first be necessary to discuss the synthesis of this compound.

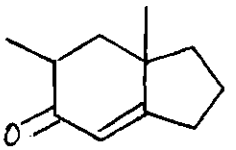
The starting material for dienone formation was 2-methylcyclopentanone which was obtained commercially. This compound was condensed in a Michael type reaction with methyl isopropenyl ketone in an alcoholic potassium hydroxide solution, to give compounds XXVIII, XXIX and XXX. It was previously reported (9) that in order to convert XXVIII and XXIX to XXX it was necessary to distill the crude reaction mixture and treat the distillate with alcoholic potassium hydroxide in which case a good yield of the desired enone (XXX) was obtained.



XXVIII



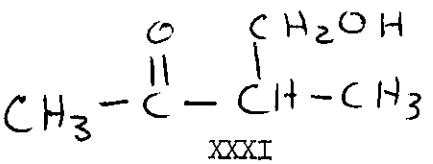
XXIX



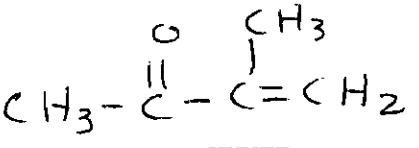
XXX

The methyl isopropenyl ketone used for this condensation was prepared by treating 2-butanone with a 45 per cent formalin solution

in the presence of dilute sodium hydroxide to bring about the formation of 3-hydroxymethyl-2-butanone (XXXI). This hydroxyketone was then distilled in the presence of anhydrous oxalic acid to yield the vinyl ketone (XXXII).

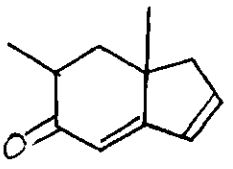


XXXI



XXXII

At this time it was necessary to introduce a double bond at the C_1 - C_2 position of the enone (XXX) to obtain the cross conjugated dienone (XVIc). It was previously found (9) that DDQ/, which is frequently used in such reactions, did not bring about the desired transformation but instead produced the linearly conjugated dienone (XXXIII).

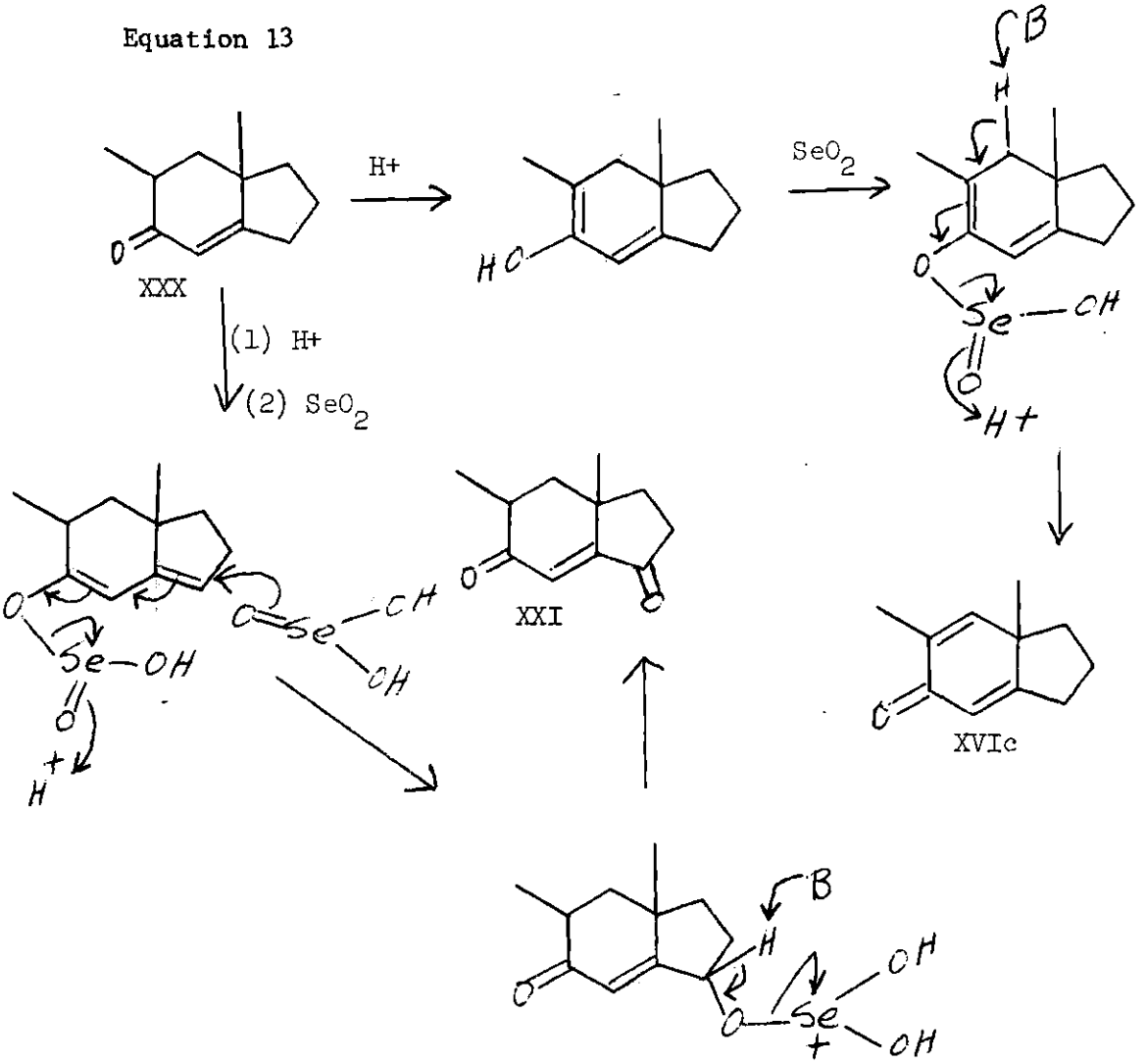


XXXIII

In order to bring about this oxidation it was necessary to treat compound XXX with selenium dioxide in an acidic media. When this was done the desired dienone (XVIc) was obtained along with a small amount

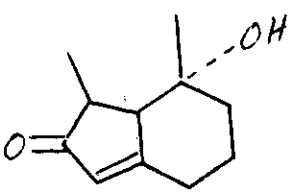
of an α,β unsaturated Diketone XXI. The production of these compounds can be rationalized by the following mechanisms.

Equation 13

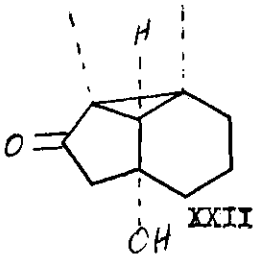


The dienone, enone and diketone were then separated by liquid chromatography on silica gel. The cross conjugated dienone was irradiated in aqueous acetic acid as described in Chapter III. Vapor phase chromatographic analysis of the crude reaction mixture showed the presence of three new compounds in addition to starting material. The

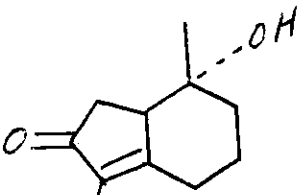
crude reaction mixture was placed on a column of silica gel and compounds XXII, XVIIIc, and XVIIIb were isolated upon elution with ether-hexane mixtures.



XVIIIc

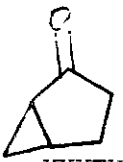


XXII

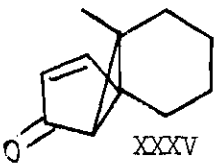


XVIIIb

These compounds were assigned their respective structures on the basis of their chemical and spectral properties. Gassmann (13) and Kropp (7) have reported that tertiary cyclopropyl hydrogens exhibit characteristic near infrared absorptions. For example, compounds XXXIV (13) and XXXV (7) have been found to absorb at 1.63 μ and 1.667 μ respectively.

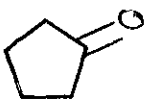


XXXIV



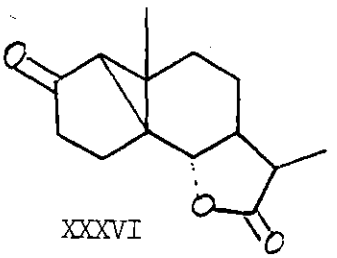
XXXV

Compound XXII showed a near ir absorption at 1.659 μ.

Compound	C=O Stretching Frequency
XVIIIc	5.84 μ
XXII	5.79 μ
	5.70 μ

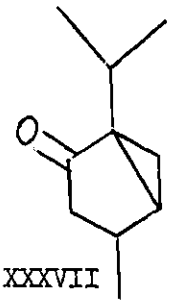
The absorption for the carbonyl group in the infrared for compound XXII lies in between that of a carbonyl group in a five membered saturated ring and in a five membered ring with a carbon-carbon double bond in conjugation.

Barton (14), Eastman (15) and Dauben (20) have reported ultraviolet absorptions for cyclic ketones with a cyclopropyl ring alpha to the carbonyl group. For example, compounds XXXVI and XXXVII have been found to absorb at λ_{max} = 214 mu (ϵ = 4,600) and λ_{max} = 210 mu (ϵ = 2,470) respectively.



XXXVI

λ_{max} = 214 mu (ϵ = 4,600)

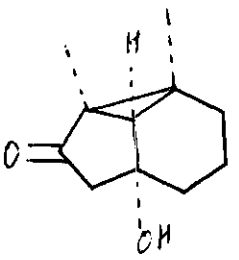


XXXVII

λ_{max} = 210 mu (ϵ = 2,470)

Compound XXII was found to absorb at 219 mu (ϵ = 3,200) under the same conditions.

The following nmr assignments have been made with regard to compound XXII.

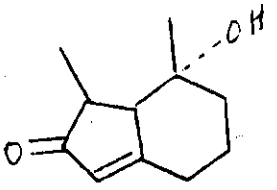


XXII

position of absorption(δ)	number of protons	assignment
4.06 (s)	1H	-O-H
2.49 (d, 18 Hz)	1H	proton at C_3
2.21 (d, 18 Hz)	1H	ptoton at C_3
1.20 (s)	3H	CH_3 group at C_1
1.17 (s)	3H	CH_3 group at C_7
1.42-2.96	7H	remaining protons

Compounds XXII, XVIIIc and XVIIIb all exhibited ir absorptions around 2.77 which is indicative of a hydroxyl group. Compound XVIIIc exhibited ir absorptions at 5.84 and 6.13μ which were indicative of a C=O group in a five membered ring, and in conjugation with a carbon-carbon double bond. Compound XVIIIb exhibited a C=O absorption at 5.87μ but its carbon-carbon double bond absorption was at 6.05μ thus indicating the double bond in compound XVIIIb was somewhat different than the one in compound XVIIIc.

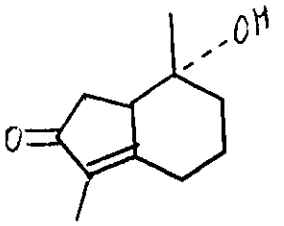
The following nmr assignments have been made in the case of compounds XVIIIc and XVIIIb.



XVIIIc

Compound XVIIIc

Position of Absorption	Number of Ptotons	Assignment
1.30 (d, J = 7, 5 Hz)	3H	CH_3 group at C_1
0.92 (s)	3H	CH_3 group at C_7
5.81 (m)	1H	proton at C_3
1.5y-3.39	9H	remaining protons

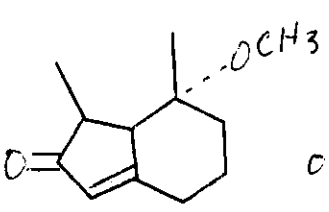


XVIIIb

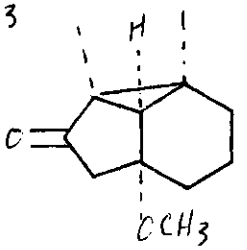
Compound XVIIIb

Position of Absorption	Number of Ptotons	Assignment
4.15 (s)	1H	-O-H
1.62 (d, J = 1 Hz)	3H	CH_3 group at C_3
0.88 (s)	3H	CH_3 group at C_7
1.20-3.00	9H	remaining protons

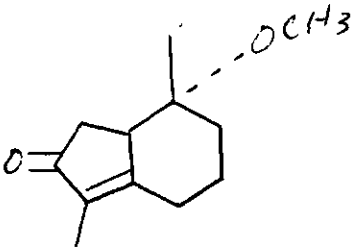
The cross conjugated dienone XVIc was also irradiated in methanolic acetic acid to determine whether or not the analogous photoproducts would arise. Vapor phase chromatographic analysis of the crude reaction mixture showed the presence of three new compounds in addition to starting material. Isolation procedure was identical to the aqueous acetic acid irradiation in which case compounds XXIII, XXIV and XXV were obtained.



XXIV



XXIII



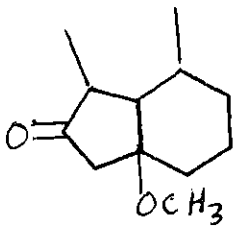
XXV

Compounds XXIII, XXIV, and XXV were found to have analogous

spectral and chemical properties to XXII, XVIIIc, and XVIIIb respectively. Compound XXIII showed a near ir absorption at 1.652 μ and uv absorptions at λ_{max} = 223 mu (ϵ = 2,900) and 297 mu (ϵ = 1,500).

Compound XXIII was treated with sodium hydride to ascertain whether the compound could accomodate a double bond at the C_3-C_9 position in which case no reaction took place indicating compound XXIII was highly strained.

It has been reported by Norin (16), Noel (17), and Fraisse-Julian (18) that cyclopropane rings which are alpha to carbonyl groups can be opened stereospecifically by reduction with lithium in liquid ammonia. The stereospecificity of the reduction is based on the fact that the bond of the three membered ring, most nearly in the plane of the pi framework, is the one which is broken. Compound XXIII was treated with a solution of lithium in liquid ammonia followed by the addition of ammonium chloride. The reaction mixture was worked up as described in Chapter III and compound XXVI was obtained.



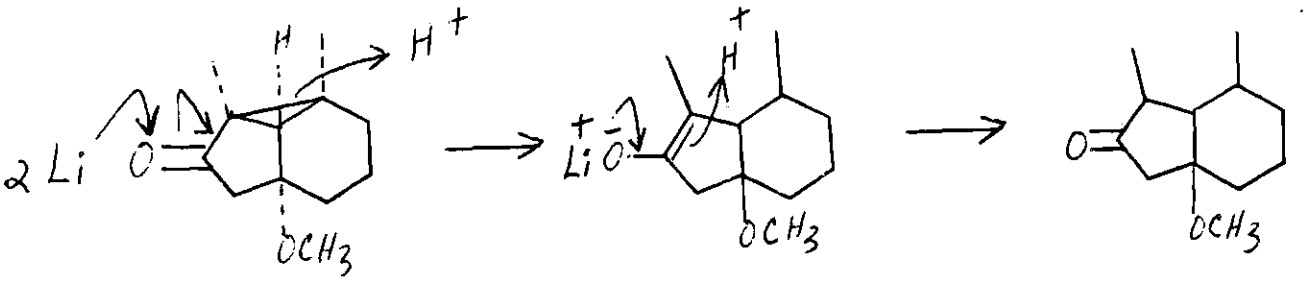
XXVI

The following nmr assignments have been made in the case of compound XXVI.

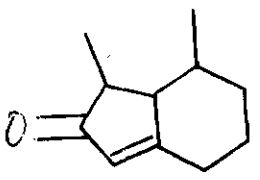
Position of Absorption (δ)	Assignment
1.12 (d, J = 6.5 Hz)	CH_3 group at C_1
0.97 (d, J = 7.0 Hz)	CH_3 group at C_7
3.12 (s)	$-O-CH_3$
1.30-2.12	remaining protons
2.18 (d, J_{ab} = 14 Hz)	proton at C_3
2.21 (d, J_{ab} = 14 Hz)	proton at C_3

Compound XXVI exhibited an ir absorption at 5.72 μ which is indicative of a C=O in a 5-membered saturated ring and did not exhibit an ultraviolet absorption above 200 mu. The mechanism of this reduction can be rationalized in the following manner.

Equation 14



Compound XXVI was treated with sodium hydride in 1,2-dimethoxyethane in which case compound XXVII was produced.



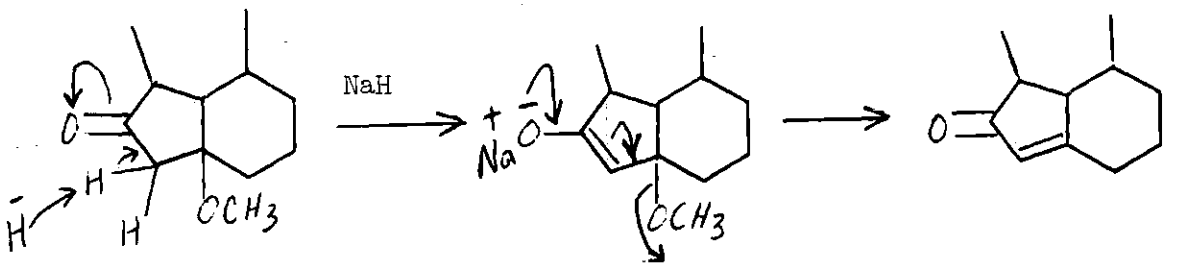
XXVII

Compound XXVII exhibited ir absorptions at 5.88 (C=O) and 6.18 μ (C=C). The following nmr assignments have been made with regard to compound XXVII.

position of absorption (δ)	number of protons	assignment
5.82 (m)	1H	proton at C_3
1.19 (d, J = 8 Hz)	3H	CH_3 group at C_1
0.92 (d, J = 7 Hz)	3H	CH_3 group at C_7
1.70-3.13	9H	remaining protons

Compound XXVII also exhibited a uv absorption at λ_{max} = 233 mu (ϵ = 11,300). The formation of compound XXVII can be rationalized by the following mechanism.

Equation 15

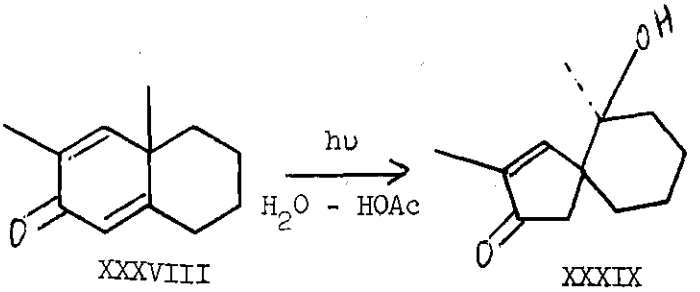


In order to determine whether compound XXV arose from XXIV by a photochemical induced isomerization, compound XXIV was irradiated for 90 min. in methanolic acetic acid. No reaction took place. This indicated that compound XXV had to arise from rearrangement of the dienone.

The production of compounds XXIII, XXIV, XXV and their alcohol analogs is in extreme contrast to the photochemical behavior of the

6/6-fused cross conjugated cyclohexadienones discussed in Chapter I. In the case of compound XXXVIII Kropp (19) has observed the major product of irradiation in an acidic media to be a spiro compound XXXIX.

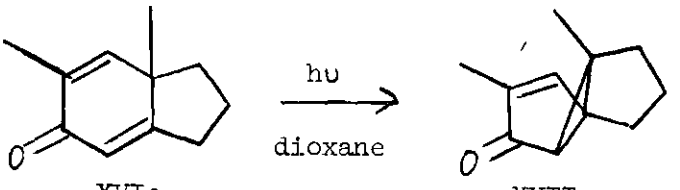
Equation 16



XXXVIII XXXIX

The behavior of 6/5-fused cross conjugated cyclohexadienones in acidic media could be rationalized in the following manner. Caine and Powers (9,10) have found that irradiation of compound XVIc in dioxane yielded XVIIc as the major product.

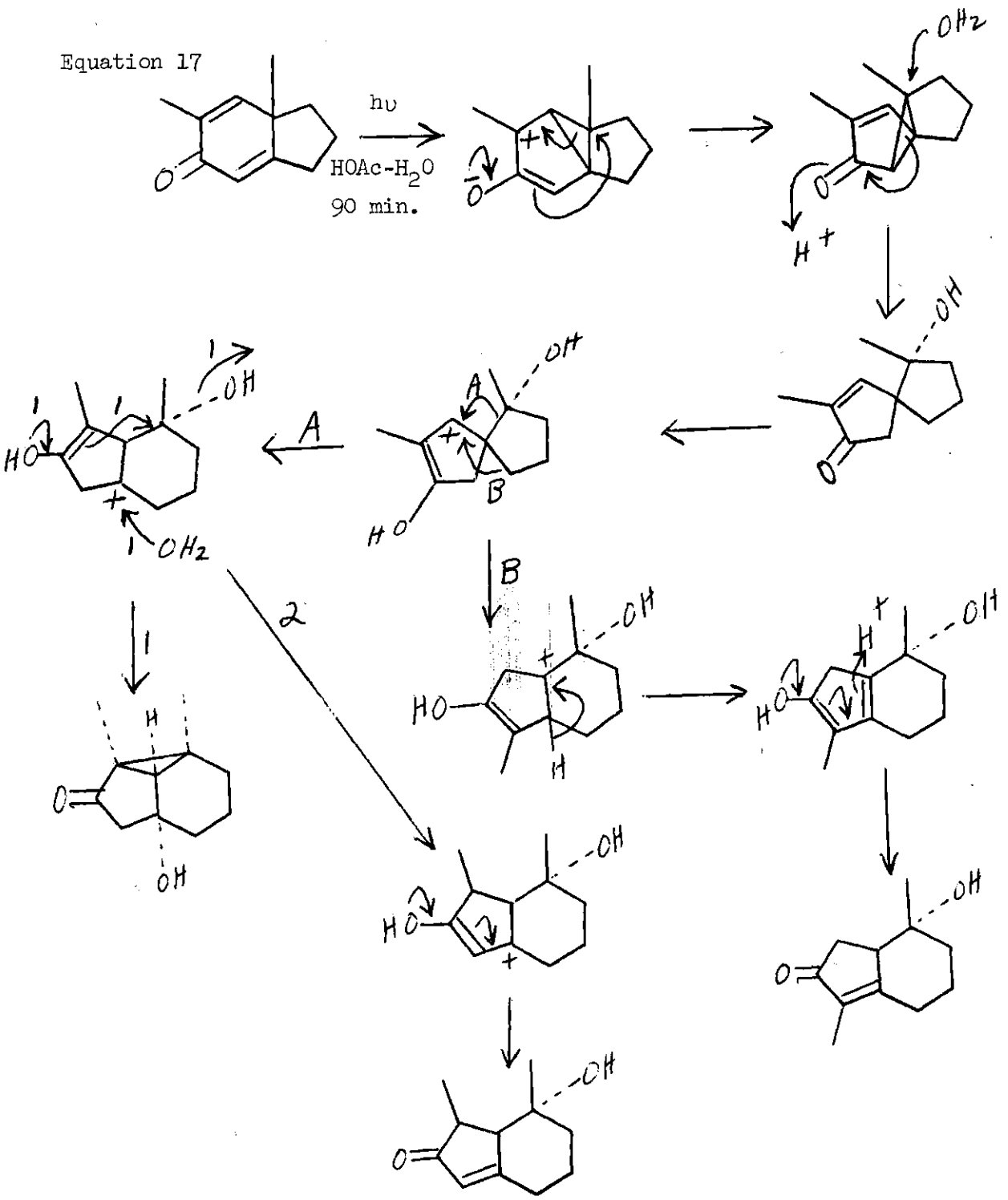
Equation 10



XVIc XVIIc

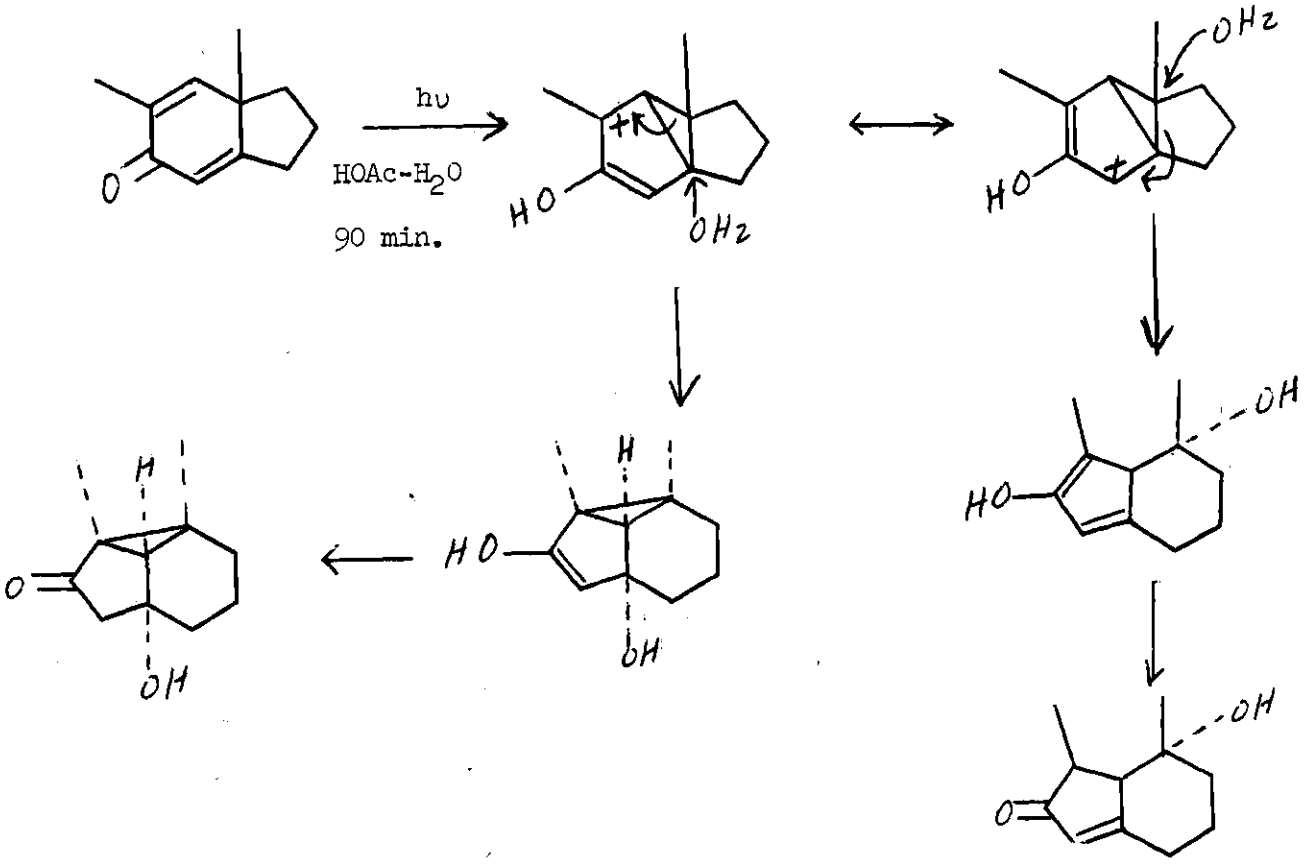
Therefore the formation of these unexpected products could be explained through formation of the lumiproduct as demonstrated in equation 17.

Equation 17



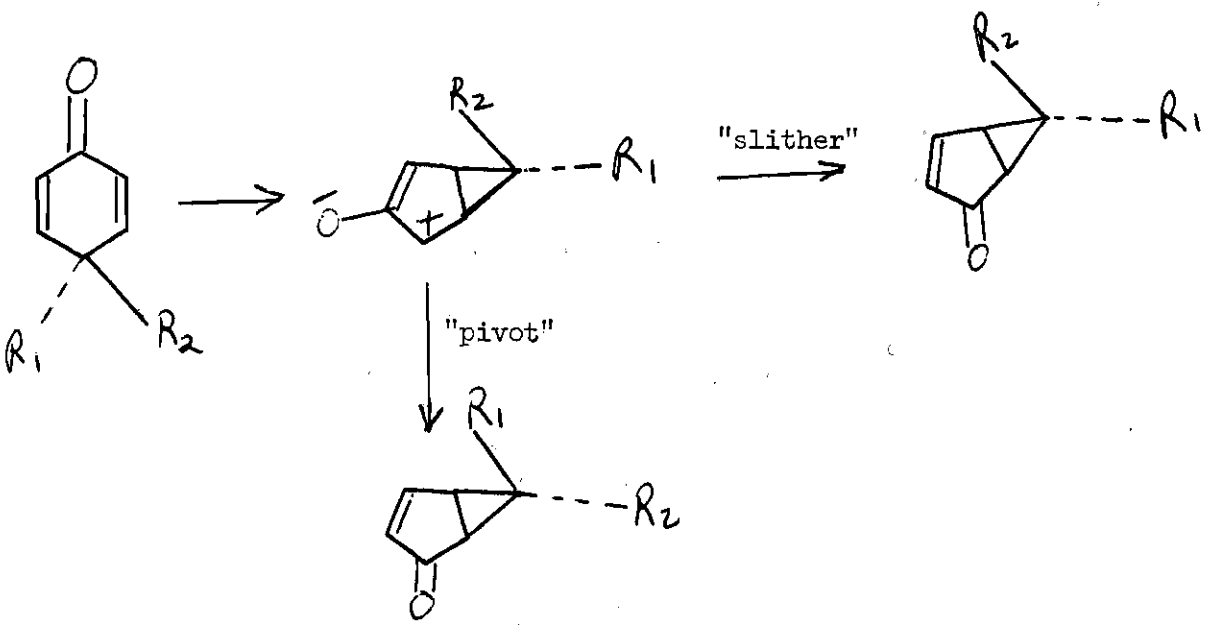
An alternative rational for the formation of two of the photo products could be through the protonated zwitterionic intermediate, as demonstrated by equation 18.

Equation 18



Recently Zimmerman and coworkers (21) have proposed two stereospecific pathways for rearrangement of the zwitterionic species as demonstrated by equation 19. Molecular orbital calculations for the ground state species has shown that the "slither" mechanism is more energetically favorable. However, if the tricyclic compounds isolated from the irradiation of XVIc in acidic media arise directly from the protonated zwitterionic intermediate a "pivot" mechanism must be employed to bring about the correct stereochemistry. This could suggest that the rearrangement to the tricyclic compounds proceed through an excited state as opposed to a "dark" reaction.

Equation 19



CHAPTER V

CONCLUSIONS

6,7a-Dimethyl-5(7aH)-indanone was irradiated in aqueous and methanolic acetic acid. 5/6-Fused compounds and tricyclic compounds were obtained. This behavior is extremely different from 6/6-cross conjugated dienones and could possibly be attributed to the photochemical reactivity of the spiro compounds which were expected to form.

CHAPTER VI

RECOMMENDATIONS

The photochemical reactions of 6/5-cross conjugated dienones in acidic media should be further investigated by observing the behavior of the unsubstituted dienone (XVIa). Such an investigation would probably clarify the factors influencing the photochemical pathways in the substituted dienones (XVIb, XVIc).

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